APPENDIX E
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APPENDIX E
DESIGN EXAMPLES

1.0 <u>DESIGN APPROACH FOR PLATE AND FRAME FILTER PRESS APPLICATIONS</u>.

Following is a typical approach and basic information that is required for the design of a plate and frame filter press and supporting systems for sludge dewatering.

a. Develop sludge characteristics and perform a mass balance. This will identifying sludge characteristics and should involve performing a material mass balance analysis based on the design flow rate around each treatment process generating sludge. From this analysis the following information should be obtained:

- Design flow rate of sludge generated per day.
- Sludge solids concentration.
- A determination of whether the sludge requires pretreatment or is stabilized.

b. Determine the method of ultimate sludge cake disposal and associated requirements. From this determination the following information should be obtained:

- Maximum allowable moisture content of the sludge cake.
- Design criteria from the concerned regulatory agencies including any contaminant specific disposal criteria.

c. Evaluate existing or proposed treatment site conditions, such as space, and determine how this system will interface with existing or proposed treatment units.

d. Determine the need and/or type of conditioning required for proper dewatering. For plate and frame filter press applications this typically includes performing bench scale and/or pilot scale testing to establish the type and dosages of chemical conditioning required, mixing requirements, and reaction period.

e. Develop design data for the selection dewatering equipment. From this process the following information should be obtained:

- Operational period.
- Filter press solids-loading rate.
- Cycle time.

f. Obtain manufacturers* catalogs and equipment selection guides.

g. Evaluate operational characteristics of the equipment, including energy requirements, specialized maintenance requirements, performance reliability, and simplicity of operation.

h. Prepare equipment design layout (i.e., engineering drawing and details) and design analysis. The design analysis should include a detailed description of the dewatering process and be supporting calculations.

i. Prepare equipment guide specifications.

2.0 DESIGN EXAMPLES.

Following are three examples that follow the design approach described in Section 1.0 of this Appendix and design calculations presented in Appendix B. The design criteria presented in these three examples are primarily based on information presented in Section 4.0 and other referenced sections of Appendix A.

DESIGN EXAMPLE NUMBER 1

2.1 PURPOSE:
To provide a design example and supporting calculations for sizing a sludge-dewatering system.

2.2 ASSUMPTIONS:
The following assumptions and criteria are used for the design of the sludge-dewatering system:

a. The characteristics of the sludge stream are given below:
Assumed type of sludge: Chemical/biological
Design liquid sludge flow = 37,850 L/d (10,000 gpd)
Concentration of solids = 2 percent
Specific gravity of feed = 1.0

b. The minimum dry solids allowed in the sludge cake will be 30 weight percent.

c. A fixed-volume recessed filter plate filter press system will be used for this example. Typical ranges of design criteria for this type of fitler press are presented in Sections 3 and 4 of Appendix A of this ETL.

d. For this example it will be assumed that treatability testing has been performed and the following design data were obtained:

Sludge Cake Characteristics:
Cake Thickness = 32 mm (1.25 inch)

Wet Cake Density = 1280 kg/m^3 (80 lb/ft^3)

Optimum Chemical Conditioning
Lime dosage (CaO) = 10 weight percent of dried solids
Ferric chloride dosage ($FeCl_3$)= 5 weight percent of dried solids

Dewatering Equipment Requirements:
Operating Time = 8 h/d, 5 d/wk

Cycle Time (Variable flow/pressure system)
Feed = 30 mm (1800 sec) at 172 kPa (25 psig)
Feed = 30 mm (1800 sec) at 345 kPa (50 psig)
Feed = 30 mm (1800 sec) at 517 kPa (75 psig)

Feed = 1 min (60 sec) at 690 kPa (100 psig)
Cake Discharge = 29 min (1740 sec)
Total = 120 min (7,200 sec) or 4 cycles/d

e. The filter press system will be housed inside a building that shall include the sludge storage tanks, sludge transport equipment (i.e., pumps), chemical conditioning tanks, chemical feed equipment, chemical storage, plate and frame filter press assembly, and filtrate and sludge cake management systems.

f. The number of filter units will be selected such that 100 percent of the design liquid sludge flow rate is filtered when the largest single unit is out of service as described in Subsection 7.3.2.1 of Appendix A. For this example it will also be assumed that the maximum filtration capacity shall be 125 percent of the design capacity when all units are in operation. Any additional specific optional features or supporting systems (i.e., precoating, air blowing, and filter media wash systems) and associated sizing requirements will be determined once the filter press has been selected.

2.3 DESIGN CALCULATIONS:

a. Determine Required Filter Volume

(1) Compute total daily sludge solids generation rate:

(a) Daily sludge solids generation rate

= [(37,850 L/d) x (0.02) x (1.0) x (1 kg/L)]
= 760 kg/d (1,670 lb/d) dry solids

(2) Compute total dry solids processed per day of filter operation:

Total dry solids dewatered = sludge+lime+ferric chloride

Sludge solids = [760 kg/d x 7 d/wk]/[5 d/wk (operation)I
= 1064 kg/d
Lime (CaO) = 1064 kg/d x (0.10) = 106 kg/d
Ferric Chloride = 1064 kg/d x (0.05) = 53 kg/d
Total dry solids per day = 1223 kg/d ~1230 kg/d (2,700 lb/d)

(3) Compute filter volume required per cycle

Filter volume per cycle
= [1230 kg/d] / [(4 cycle/d) x (1280 kg/m^3) x (0.30)]
= 0.8 m^3 (29 ft^3) of sludge/cycle

b. Selection of Efficient Filter Unit

(1) Determine the Pressure Filter Sizes Available From the manufacturer*s catalogs, determine the sizes of various filter units. Tabulate the filter area available with and without the single largest unit. See Attached Table E-l.

(2) Select Proper Filter Unit
The most efficient and manageable filter unit assembly is the one that has the fewest operating units and provides nearly 100 percent operating capacity when one unit is out of service , and about 25 percent extra capacity when all units are in operation. Based on this method the proper unit selection from Table E-l would be Unit F. This selection has a total of 4 units, including 3 operating units and one standby unit. This assembly will provide 105 percent of the design daily requirement when one unit is not operating, and 140 percent of the design daily dewatering capacity when the standby unit is in operation. Although Unit D required the same number of units and has the same overall operating capacities, this selection is the maximum capacity of this size unit and would not allow for additional future capacity, if necessary. A typical schematic layout of the filter press units and supporting equipment is presented in Figure E-1.

Although the method presented provides a direct approach of determining the optimal selection of the size and number of required presses, an economic and technical evaluation of several alternatives that achieve the minimum should be considered prior to the final selection of the appropriate filter size and number of associated units.

TABLE E-1
SELECTION CHART OF RECESSED FIXED-VOLUME
PLATE AND FRAME FILTER PRESS UNITS

Unit I.D.	Filter Size (mm)[1]	No. of Chambers	Volume of Each Unit (m^3)	Minimum Units Required	Total Volume with Minimum Units (m^3)	Total Units with one Standby	Total Volume with One Standby Unit (m^3)	Volume without standby Unit (%)[2]	Volume with standby Unit (%)[3]
A	470	27	0.11	8	0.88	9	0.99	110	124
B	470(max)	40	0.20	5	1.0	6	1.2	125	150
C	630	27	0.23	4	0.92	5	1.15	115	144
D	630(max)	30	0.28	3	0.84	4	1.12	105	140
E	800	16	0.23	4	0.92	5	1.15	115	144
F	800	20	0.28	3	0.84	4	1.12	105	140
G	800(max)	40	0.57	2	1.14	3	1.71	143	214

Conversions: 1 m^3= 35.3 ft^3, 1 inch= 25 mm.
[1] Data compiled from actual manufacturer's data.
[2] Total volume without standby unit/actual volume required.
[3] Total volume with one standby unit/actual volume required.

(3) Supporting Systems
Based on the specific filter press selected, requirements for sizing supporting systems such as precoating, air blowing, and media washing systems along with utility requirements, will be determined from the information provided in Section 4.0 of Appendix A and from equipment manufacturers or suppliers. However, for this example these requirements will not be further defined.

c. Sludge Storage, Conditioning, and Feed Systems

(1) Development of System Components
The flow scheme, shown in Figure E-1 involves sludge storage, conditioning, and feed systems. The associated design criteria related assumptions are presented below are primarily based on information presented in Section 4.0 of Appendix A.

(a) A sludge storage tank will be located upstream of the sludge conditioning system.

(b) A dry lime storage and mixing system will be used downstream of the sludge storage tank. This system will have the capacity to store a 30 day supply of hydrated lime, that will be provided in 45 kg (100 lb) bags in 96 percent purity. A hydrated bagged lime system was selected because of the low quantity of lime required, as described in Subsection 4.6.1 of Appendix A. The dry lime will be fed in the required amount into a dilution tank by two volumetric feeders. A 10 percent slurry of calcium hydroxide ($CaOH_2$) by weight will be mixed prior to being metered into the conditioning tank.

(c) A ferric chloride storage and mixing system will be used downstream of the sludge storage tank. This system will have the capacity to store a 30 day supply of 40 percent ferric chloride solution. The ferric chloride will be diluted to obtain a 10 percent solution prior to being metered into the conditioning tank.

(d) A sludge transfer system will be used to pump the sludge from the sludge storage tank to the conditioning tank. If required, the sludge will pass through an in-line grinder prior to sludge transfer pumping system. this in-line grinder will improve sludge mixing and flow characteristics and protect downstream pumping and dewatering equipment.

(e) The conditioning system will consist of a conditioning tank to which the sludge and conditioning chemicals are added and assumed to be completely mixed. The conditioned sludge will then pumped to the filter press units.

(f) The feed pump system will consist of pumps with the capacity to deliver the sludge to the filter press at the following pressure stepping conditions, as described in Subsection 4.3.1 of Appendix A of this ETL: 30 mm (1800 sec) at 172 kPa (25 psig), 30 mm (1800 sec) at 345 kPa (50 psig), 30 mm (1800 sec) at 517 kPa (75 psig), and 1 mm (60 sec) at 690 kPa (100 psig).

(2) Compute the size of sludge storage required: Assume a provision for sludge storage for a 4 day period (GLUMRB 1990)

Volume of sludge to be stored = 37,850 L/d x 4 days
= 151,400 L (40,000 gallons)

Therefore a storage tank or tanks should be selected with a capacity of 152,000 L or 152 m^3 (40,000 gallons) from manufacturer*s catalogs.

(3) Compute the size of lime storage facility required:

Provide a 30 day or 1 month storage. Assume approximately 4.33 wk/mo.

Lime required per 8-h day = 106 kg/d
Lime required per month = 106 kg/d x 5 d/wk x 4.33 wk/mo
= 2,300 kg/mo (5,070 lb/mo)

Assume use of hydrated lime at 96 percent purity.

For 30 day storage quantity of hydrated lime required
= [(2,300 kg/mo)/0.96] x [74(MW of $Ca(OH)_2$)/56(MW of CaO)]
= 3,170 kg/mo (7,160 lb/mo)

Number of bags of hydrated lime needed per month
= (3,170 kg/mo)/(45 kg/bag) = 71 bags/mo

Therefore storage should be provided for 80 bags.

The capacity of the hydrated lime feed hopper should be large enough to contain one day*s supply of lime.

Bags needed per day = [71 bags/mo]/((5 d/wk) x (4.33wk/mo)]
= 4 bags/day

Based of the bulk density of hydrated lime of 480 kg/in^3 (30 lb/ft^3) and allowing provisions for two hoppers to hold 2 bags of hydrated lime each.

Volume required for each hopper =
[(2 bags) x (45 kg/bag)]/[480 kg/in^3] = 0.2 in^3 (7 ft^3)

Therefore each hopper should have a minimum capacity of 0.2 m^3 (7 ft^3) and will feed lime into a mixing tank where, a 10 weight percent lime slurry will be prepared prior to being metered into the sludge conditioning tank.

(4) Compute the size of the ferric chloride storage facility required:

Provide 30 day or 1 month storage at operating condition.

Ferric chloride required per 8-h day = 53 kg/d
Ferric chloride required per month
= 53 kg/d x 5 d/wk x 4.33 wk/mo = 1150 kg/mo (2,530 lb/mo)

Assume use of ferric chloride at 40 percent purity with a density of 1.45 kg/L (12 lb/gal).

For 30-d storage quantity of ferric chloride required
= [(1,150 kg/mo)/(0.40 x 1.45 kg/L] = 1990 L/mo (530 gal/mo)

Therefore minimum storage should be provided for 2000 L or 2 m^3 (550 gallons).

(5) Compute size of the sludge pump used prior the conditioning tank:

Assume the conditioning tank is connected to all the filter process, and all the operating filters are fed at one time.

Total sludge pumped per operating day
= (37,850 L/d x 7 d/wk)/(5 d/wk operating) = 53,000 L/d
= (14,000 gal/d)

Pumping rate per cycle (filling time 100 mm [6000 sec])
= [53,000 L/d]/[(4 cycle/day) x (6000 sec/cycle)]
= 2.2 L/s (35 gpm)

Therefore the total minimum required pumping capacity is 2.2 L/s (35 gpm). For this application a minimum of two pumps should be provided, one operating pump and one standby pump. To size these pumps the system hydraulic (static and dynamic) head requirements would need to be determined based on specific system requirements in addition to a safety factor of 10 to 25 percent, as described in Subsection 7.2.2.1 of Appendix A, to overcome any effects from the sludge such as it thixotropic properties. Using the pump capacity and head, manufacturer*s catalogs should be obtained and the appropriate pump should be selected.

(6) Compute the size if the conditioning tank:

Assume use of an in-line conditioning tank with a 10 minute (600 sec) detention and mixing time.

Volume required for conditioning tank
= 2.2 L/s x 600 sec = 1320 L (350 gallons)

Therefore a conditioning tank should be selected with a minimum capacity of 1320 L or 1.32 m^3 (350 gallons). This conditioning tank should also be equipped with a mixer and level switches to control the operation of the sludge and dilute conditioning chemical metering pumps.

(7) Compute the size of the sludge feed pumps to the filter presses:

Each filter press will be equipped with one operating sludge feed pump and one standby pump. The total quantity of conditioned sludge plus chemical solution to the filter presses follows:

Sludge quantity = 53,000 L/d

Water in lime at 10 percent solution =
[106 kg/d]/[(0.l x 1 kg/L)] = 1,060 L/d

Water in ferric chloride at 10 percent solution =
[53 kg/d]/[(0.l x 1 kg/L)] = 530 L/d

Total quantity to be pumped =
[53,000 + 1,060 + 530] L/d = 54,590 L/d
~ 54,600 L/d (14,440 gal/d)

Pumping rate for each pump when 3 filter units are operating = [54,600 L/s]/[(3 pumps) x (4 cycles/day) x
(6000 sec/cycle)] = 0.76 L/s (12 gpm)

Therefore the total minimum pumping capacity for each operating and standby pump is 0.76 L/s (12 gpm) at a filter press pressure of 690 kPa (100 psig) (maximum pressure condition specified). However, prior to selection of the appropriate pump any additional system head losses in addition to safety factor requirements should be determined and combined with the required filter press pressure to determine the overall head requirements. Once this determination is made, manufacturer*s catalogs should be obtained and an appropriate pump should be selected.

d. Sludge Cake

(1) Compute the total sludge dry cake solids:
The filter cake contains sludge solid, lime, and ferric chloride. For this example it will be assumed that 100 percent of the condition chemicals are incorporated into the sludge cake and that the dewatering facility provides 98 percent solids capture.

Sludge solids in cake = 0.98 x 1,060 kg/d	=	1,039 kg/d
Lime solids in cake = 1.00 x 106 kg/d	=	106 kg/d
Ferric chloride in cake = 1.00 x 53 kg/d	=	120 kg/d
Total dry solids in sludge cake	=	1,198 kg/d

$\sim$ 1200 kg/d (2,640 lb/d)

(2) Compute the volume of sludge cake and required storage:

The wet sludge cake has a bulk density of 1,280 kg/in^3 (80 lb/ft^3). For this example it will be assumed that the sludge will be discharged directly into a hopper for direct dumping into transport trucks for offsite disposal and a 4 day volume of sludge cake storage will be provided (GLUMRB 1900).

Volume of the sludge cake generated on a daily basis:
[(1,200 kg/d)]/[(1,280 kg/m^3) x (0.30)] = 3.1 m^3/d (110 ft^3/d)

Volume of sludge cake storage required per press =
((3.1 m^3/d) x (4-d)]/[3 filter press] = 4.1 m^3/press

Therefore the volume of the storage receptacle for each of the 3 operating presses will be 4.1 m^3 (150 ft^3).

e. Filtrate Quality

The filtrate generated in the sludge-dewatering process shall be discharged into a sump with a 1 day capacity of filtrate and/or combined with other treatment process overflow streams. A portion of this filtrate may then be either used in the filter dewatering process for sub-cycles, such as filter media precoating, or returned to the headworks of the treatment process with the remaining filtrate.

(1) Compute volume of filtrate

Filtrate volume = 53,000 L/d-[(3.1 m^3/d) x (1,000 L/m^3)]
= 49,900 L/d
Water in lime solution = 1,060 L/d

Water in ferric chloride solution = 530 L/d

Total of return flow = 51,490 L/d
~ 51,500 L/d (13,600 gpd)

(Note that in addition to the items listed above, additional of process water used in the dewatering system such as water needed for filter media washing will need to be considered. However, since these quantities are specific to the dewatering equipment selected and are not included for this example.)

(2) Compute total solids in the return flow:

Total solids in conditioned sludge = 1,230 kg/d
Total solids in sludge cake = 1,200 kg/d
Difference total solids in return flow = 30 kg/d
(~70 lb/d)

Therefore the sump for this example should be sized to store 51,500 L or 51.5 m^3 (13,600 gallons) based on the 1 day storage basis.

f. Design Details

A diagram of the design of the filter press assembly is presented in Figure E-1.

DESIGN EXAMPLE NUMBER 2

3.0 PURPOSE:
To provide a design example and supporting calculations for sizing a sludge-dewatering system.

3.1 ASSUMPTIONS:
The following assumptions and criteria are used for the design of the sludge–dewatering system:

a. The characteristics of the sludge stream are given below:

Assumed type of sludge: Biological
Design daily liquid sludge flow = 80,000 L/day (21,100 gpd)
Concentration of solids = 5 percent
Specific gravity of feed = 1.0

b. The minimum dry solids allowed in the sludge cake will be 25 weight percent.

c. A variable-volume recessed filter plate filter press system will be used for this example. Typical ranges of design criteria for this type of fitler press are presented in Sections 3 and 4 of Appendix A of this ETL.

d. For this example it will be assumed that treatability testing has been performed and the following design data were obtained:

Sludge Cake Characteristics:
Cake Thickness = 32 mm (1.25 inch)
Wet Cake Density = 1120 kg/m^3 (70 lb/ft^3)
Optimum Chemical Conditioning:
Lime dosage (CaO) = 5 weight percent of dried solids
Organic Polymer = 2 weight percent of dried solids
Dewatering Equipment Requirements:
Operating Time = 8 h/d, 5 d/wk
Cycle Time
Feed = 20 min (1200 sec) at 345 kPa (50 psig)
Compression = 15 min (900 sec) at 1550 kPa (225 psig)
Cake Discharge = 25 min (1500 sec)
Total = 60 min (3600 sec) or 8 cycles/d

e. The filter press system will be housed inside a building that shall include the sludge storage tanks, sludge transport equipment (i.e., pumps), chemical conditioning tanks, chemical feed equipment, chemical storage, plate and frame filter press assembly, and filtrate removal and sludge cake management systems.

f. The number of filter units will be selected such that 100 percent of the design liquid sludge flow rate is filtered when the largest single unit is out of service as described in Subsection 7.3.2.1 of Appendix A. For this example it will also be assumed that the maximum filtration capacity shall be 125 percent of the design capacity when all units are in operation. Any additional specific optional features or supporting systems (i.e., precoating, air blowing, and filter media wash systems) and associated sizing requirements will be determined once the filter press has been selected.

3.2 DESIGN CALCULATIONS:

a. Determine Required Filter Volume

(1) Compute total daily sludge solids generation rate:

Daily sludge solids generation rate
= [(80,000 L/d) x (0.05) x (1.0) x (1 kg/L)]
= 4000 kg/d (8,800 lb/d) dry solids

(2) Compute total dry solids processed per day of filter operation:

Total dry solids dewatered = sludge+lime+polymer

Sludge solids = [4000 kg/d x 7 d/wk]/[5 d/wk (operation)]
= 5600 kg/d
Lime (CaO) = 5600 kg/d x (0.05) = 280 kg/d
Polymer = 5600 kg/d x (0.02) = 112 kg/d
Total dry solids per day =5992kg/d ~6000 kg/d
(13,200 lb/d)

(3) Compute filter volume required per cycle

Filter volume per cycle
= [6000 kg/d]/[(8 cycle/d) x (1120 kg/m^3) x (0.25)]
= 2.7 m^3 (95 ft^3) of sludge/cycle

b. Selection of Efficient Filter Unit

(1) Determine the Pressure Filter Sizes Available From the manufacturer*s catalogs to determine the sizes of various filter units. Tabulate the filter area available with and without the single largest unit. See Attached Table E-2.

(2) Select Proper Filter Unit
The most efficient and manageable filter unit assembly is the one that has the fewest operating units and provides nearly 100 percent operating capacity when one unit is out of service, and about 25 percent extra capacity when all units are in operation. Based on this method the proper unit selection from Table E-2 would be Item D. This selection has a total of 5 units, including 4 operating units and one standby unit. This assembly will provide 104 percent of the design daily requirement when one unit is not operating, and about 133 percent of the design daily dewatering capacity when the standby unit is in operation. Although Unit C has the same number of units and has the same overall operating capacities, this selection is the maximum capacity of this size unit and would not allow for additional future capacity, if necessary. A typical schematic layout of the filter press units and supporting equipment is presented in Figure E-2.

Although the method presented provides a direct approach of determining the optimal selection of the size and number of required presses, an economic and technical evaluation of several alternatives that achieve the minimum should be considered prior to the final selection of the appropriate filter size and number of associated units. For example, by comparing different alternatives in Table E-2, Item C and Item D are both similar for the number of units and operating capacities. However, although Item C is at its maximum size, it has some additional capacity (i.e., 105 percent) and would less expensive than Item D and may be suitable if no additional capacity is required.

TABLE E-2
SELECTION CHART OF RECESSED VARIABLE-VOLUME
PLATE AND FRAME FILTER PRESS UNITS

Unit I.D.	Filter Size (mm)[1]	No. of Chambers	Volume of Each Unit (ft^3)	Minimum Units Required	Total Volume with Minimum Units (ft^3)	Total Units with one Standby	Total Volume with One Standby Unit (ft^3)	Volume without standby Unit (%)[2]	Volume with standby Unit (%)[3]
A	630(max)	33	0.28	10	2.8	11	3.1	104	115
B	800(min)	16	0.23	12	2.8	13	3.0	104	111
C	800(max)	53	0.71	4	2.8	5	3.6	104	133
D	1000(min)	31	0.71	4	2.8	5	3.6	104	133
E	1000(max)	62	1.42	2	2.8	3	4.3	104	159
F	1200(min)	62	2.12	2	4.2	3	6.4	156	237

(3) Supporting Systems
Based on the specific filter press selected, requirements for sizing supporting systems such as precoating, air blowing, and media washing systems along with utility requirements, will be determined from the information provided in Section 4.0 of Appendix A and from equipment manufacturers or suppliers. However, for this example these requirements will not be further defined.

c. Sludge Storage, Conditioning, and Feed Systems

(1) Development of System Components
The flow scheme shown in Figure E-2 involves sludge storage, conditioning, and feed systems. The associated design criteria related assumptions are presented below are based on information presented in Section 4.0 of Appendix A.

(a) A sludge storage tank will be located upstream of the sludge conditioning system.

(b) A dry lime storage and mixing system will be used downstream of the sludge storage tank. This system will have the capacity to store a 30 day supply of hydrated lime, that will be provided in 45 kg (100 lb) bags. The dry lime will be fed in the required amount into a dilution tank by two volumetric feeders. A hydrated bagged lime system was selected because of the low quantity of lime required as described in Subsection 4.6.1 of Appendix A. A 10 percent slurry of calcium hydroxide ($CaOH_2$) by weight will then be mixed and then be metered into the conditioning tank.

(c) A dry polymer storage and mixing system will be used downstream of the sludge storage tank. This system will have the capacity to store a 30 day supply of dry polymer supplied in 22 kg (50 lb) bags. The dry polymer will be fed in the required amount into a dilution tank by two volumetric feeders. A 5 percent solution will then be mixed prior to being metered into the conditioning tank.

(d) A sludge transfer system will be used to pump the sludge from the sludge storage tank to the conditioning tank. If required, the sludge will be passed through an in-line grinder prior to sludge transfer pumping system. This in-line grinder will improve sludge mixing and flow characteristics and protect downstream pumping and dewatering equipment.

(e) The conditioning system will consist of a conditioning tank to which the sludge and conditioning chemicals are added and assumed to be completely mixed. The conditioned sludge will then be pumped to the filter press units.

(f) The feed pump system will consist of pumps with the capacity to deliver the sludge to the filter press at the design pressure of 345 kPa (50 psig) for 20 minutes (1200 seconds). After completion of the feed cycle, the compression cycle will proceed by pumping water at 1550 kPa (225 psig) for 15 minutes (900 seconds) behind the filter press diaphragms for inflation.

(2) Compute the size of sludge storage required:
Assume provisions for sludge storage for a 4 day period (GLUMRB 1990).

Volume of sludge to be stored = 80,000 L/d x 4 day
= 320,000 L (84,400 gallons)

Therefore a storage tank or tanks should be selected with a capacity of 320,000 L or 320 m^3 (85,000 gallons) from manufacturer* s catalogs.

(3) Compute the size of lime storage facility required:

Provide a 30 day or 1 month storage and assume 4.33 wk/mo and the use of hydrated lime at 90 percent purity.

Lime required per 8 h day= 280 kg/d (620 lb/d)
Lime required per month = 280 kg/d x 5 d/wk x 4.33 wk/mo
= 6100 kg/mo (13,430 lb/mo)

For 30 day storage quantity of hydrated lime required
= [(6100 kg/mo)/0.9] x [74 (MW of $Ca(OH)_2$)/56 (MW of CaO)]
= 8,960 kg/mo (19,740 lb/mo)

Number of bags of hydrated lime needed per month
= (8,960 kg/mo)/(45 kg/bag)= 199 bags/mo

Therefore storage should be provided for 200 bags.

The capacity of the hydrated lime feed hopper should be large to contain one day*s supply of lime.

Number of bags needed per day = [199 bags/mo]/ [(5 d/wk) x (4.33 wk/mo) = 10 bags/day

Based of the bulk density of hydrated lime of 480 kg/m^3 (30 lb/ft^3) and allowing provision for two hoppers to hold 5 bags of hydrated lime each.

Volume required for each hopper=
[(5 bags) x (45 kg/bag)]/[480 kg/m^3]= 0.47 m^3 (17 ft^3)

Therefore each hopper should have a minimum capacity of 0.5 m^3 (17 ft^3) and will feed lime into a mixing tank where, a 10 weight percent lime slurry will be prepared prior to being metered into the sludge conditioning tank.

(4) Compute the size of the polymer storage facility required:

Provide 30 day or 1 month storage.

Polymer required per 8-h day = 112 kg/d (250 lb/d)
Polymer required per month = 112 kg/d x 5 d/wk x 4.33 wk/mo = 2425 kg/mo (5,420 lb/mo)

Number of bags of polymer needed per month
= (2425 kg/mo)/(22 kg/bag)= 110 bags/mo

Therefore storage should be provided for 110 bags.

The capacity of the polymer feed hopper should be large to contain one day*s supply of polymer.

Number of bags needed per day = (112 kg/d)/(22 kg/bag)
= 5 bags

The bulk density of the polymer is assumed to be 320 kg/in^3 (20 lb/ft^3) and the daily supply will be stored in two hoppers.

Volume required for each hopper =
[112 kg/d)]/[2 x 320 kg/in^3] = 0.2 in^3 (7 ft^3)

Therefore each hopper should have a minimum capacity of 0.2 m^3 (7 ft^3) and will feed polymer to a mixing tank for preparation of the 5 percent solution prior to being metered into the sludge conditioning tank.

(5) Compute size of the sludge pump used prior the conditioning tank:

Assume the conditioning tank is connected to all the filter process, and all the operating filters are fed at one time.

Total sludge pumped per operating day =
(80,000 L/d x 7 d/wk)/(5 d/wk operating)=112,000 L/d

Pumping rate per cycle (filling time 20 min [1200 sec])
= [112,000 L/d]/[(8 cycle/day) x (1200 sec/cycle)]
= 12 L/s (185 gpm)

Therefore the total minimum required pumping capacity is 12 L/s (185 gpm). For this application a minimum two pumps should be provided, one operating pump and one standby pump. To size these pumps and the system hydraulic (static and dynamic) head requirements would need to be determined in addition to a safety factor of 10 to 25 percent, as described in Subsection 7.2.2.1 of Appendix A, to overcome any effects from the sludge such as it thixotropic properties. Using the pump capacity and head, manufacturer*s catalogs should be obtained and the appropriate pump should be selected.

(6) Compute the size if the conditioning tank:

Assume use of an in-line conditioning tank with a 10 minute (600 sec) retention and mixing time.

Volume required for conditioning tank
= 12 L/s x 600 sec= 7200 L (1,900 gallons)

Therefore a conditioning tank should be selected with a 7200 L or 7.2 m^3 (1,900 gallon) working capacity. This conditioning tank should also be equipped with a mixer and level switches to control the operation of the sludge and conditioning chemical metering pumps.

(7) Compute the size of the sludge feed pumps to the filter presses:

Each filter press will be equipped with one sludge operating feed pump and one standby pump. The total quantity of conditioned sludge plus chemical solution to the filter presses follows:

Sludge quantity= 112,000 L/d (29,540 gpd)
Water in lime at 10 percent solution
= [280 kg/d]/[(0.1 x 1 kg/L)] = 2,800 L/d (740 gpd)

Water in polymer at 5 percent solution
= [112 kg/d]/[(0.05 x 1 kg/L)] = 2,240 L/d (600 gpd)

Total quantity to be pumped
= (112,000 + 2,800 + 2,240) L/d = 117,040 L/d (30,880 gpd)

Pumping rate for each pump when 4 filter units are operating= [117,040 L/d]/[(4 pumps) x (8 cycles/day) x (1,200 sec/cycle)]= 3 L/s (50 gpm)

Therefore the total required pumping capacity for each operating and standby pump is 3 L/s (50 gpm) at a filter press pressure of 345 kPa (50 psig). However, prior to selection of the appropriate pump any additional system head losses in addition to safety factor requirements should be determined and combined with the required filter press pressure to determine the overall head requirements. Once this determination is made, manufacturer*s catalogs should be obtained and an appropriate pump should be selected.

d. Sludge Cake

(1) Compute the total sludge cake solids:

The filter cake contains sludge solid, lime, and polymers. For this example it will be assumed that 75 percent of the condition chemicals are incorporated into the sludge cake and that the dewatering facility provides 95 percent solids capture.

Sludge solids in cake = 0.95 x 5600 kg/d = 5320 kg/d
Lime solids in cake = 0.75 x 280 kg/d = 210 kg/d
Polymer solids in cake= 0.75 x 112 kg/d = 84 kg/d
Total dry solids in sludge cake = 5620 kg/d (12,370 lb/d)

(2) Compute the volume of sludge cake and required storage:

The sludge cake has a bulk density of 1120 kg/m^3 (70 lb/ft^3). For this example it will be assumed that the sludge will be discharged directly into a hopper for direct dumping into transport trucks for offsite disposal and a 4 day volume of sludge cake storage will be provided.

Volume of the sludge cake generated on a daily basis
[(5620 kg/d)]/[(1120 kg/m^3) x (0.25)] = 20 m^3 (710 ft^3/d)

Volume of sludge cake storage required per press=
[(20 m^3/d) x (4-d)]/[4 filter press]= 20 m^3/press

Therefore the volume of the storage receptacle for each of the 4 operating presses will be 20 m^3 (710 ft^3).

e. Filtrate Quality

The filtrate generated in the sludge-dewatering process shall be discharged into a sump with a 1 day capacity of filtered an/or combined with other treatment process overflow streams. A portion of this filtrate may then be either used in the filter dewatering process for sub-cycles, such as filter media precoating, or returned to the headworks of the treatment process with the remaining filtrate.

(1) Compute volume of filtrate

Filtrate volume
= 112,000 L/d – [(20 m^3/d) x (1,000 L/m^3)] = 92,000 L/d
Water in lime solution = 2,800 L/d
Water in polymer solution = 2,240 L/d
Total of return flow = 97,040 L/d (25,600 gpd) or 1.1 L/s (18 gpm)

(Note that in addition to the items listed above additional of process water used in the dewatering system mechanical such as water needed for filter media washing, cake extraction, and diaphragm losses will need to be considered. However, since these quantities are specific to the dewatering equipment selected and are not included for this example.)

(2) Compute total solids in the return flow:

Total solids in conditioned sludge = 5990 kg/d
Total solids in sludge cake = 5620 kg/d
Difference total solids in return flow = 370 kg/d (815 lb/d)

Therefore the sump for this example should be sized to store 97,100 L or 97 m3 (25,600 gallons) based on the 1 day storage basis.

f. Design Details
A diagram of the design of the filter press assembly is presented in Figure E-2.

DESIGN EXAMPLE NUMBER 3

4.0 PURPOSE:
To provide a preliminary design example assuming that both chemical (metal hydroxide) and biological sludge are generated from a contaminated water source. This example is limited to the selection of the press. Once this determination is made, the calculations for supporting equipment can be performed, as demonstrated in Examples #1 and #2.

4.1 ASSUMPTIONS:
The following assumptions and criteria are used for the design of the sludge-dewatering system:

a. The characteristics of ground water to be treated:

(1) Assumed type of ground water contamination: Landfill leachate containing heavy metals (i.e., chromium) and organics (i.e, volatiles and semivolatiles). Specific influent characteristics:

Chromium (Hexavalent)=10 mg/L (required effluent 0.02 mg/L)
BOD_5=900 mg/L (required effluent 30 mg/L)
COD=1,600 mg/L

(2) Design influent flow = 6.3 L/s (100 gpm)

b. For this application it is assumed that the contaminated ground water is first treated to remove the metals by a reduction, flocculation, and clarification process which results in the generation of a metal hydroxide sludge. Following metals removal the ground water is then treated to removed organics contamination by an activated sludge process which generates biological sludge. The two separate sludge streams generated are then sent to separate filter presses. fixed-volume recessed filter plate filter press system will be used.

c. For this example it is assumed that treatability testing has been performed and the following data were obtained:

(1) Metal Hydroxide Sludge:
Sludge Feed Characteristics:
Concentration of Solids = 1 percent
Solids Production = 70 mg/L
Specific Gravity = 1.0
Sludge Cake Characteristics:
Cake Thickness = 32 mm (1.25 inch)
Wet Cake Density = 1200 kg/m^3 (75 lb/ft^3)

Minimum solids = 30 percent
Optimum Chemical Conditioning:
Polymer = 1 weight percent of dried solids

(2) Biological Sludge:
Sludge Feed Characteristics:
Concentration of Solids = 2 percent
Liquid Sludge Stream
(includes influent and recycle streams) = 10,900 L/d (2 gpm)
Specific Gravity = 1.0
Sludge Cake Characteristics:
Cake Thickness = 32 mm (1.25 inch)
Wet Cake Density = 1120 kg/m3 (70 lb/ft^3)
Minimum solids = 30 percent
Optimum Chemical Conditioning:
Lime (CaO) = 30 weight percent of dried solids

d. Fixed—volume recessed filter plate filter press systems will be used for this example. Typical ranges of design criteria for this type of filter press are presented in Sections 3 and 4 of Appendix A of this ETL. For each type of sludge the following filter press information applies (See Table A-4, Appendix A):

(1) Metal Hydroxide Sludge:
Cycle Time = 240 minutes (maximum 4 cycles per day)
Operating Pressure = 690 or 1550 kPa (100 or 225 psi)

(2) Biological sludge (assume industrial type):
Cycle Time = 240 minutes (maximum 4 cycles per day)
Operating Pressure = 1550 kPa (225 psi)

4.2 DESIGN CALCULATIONS:

a. Determine Required Filter Volume:

Metal Hydroxide Sludge:

(1) Compute total daily sludge solids generation rate:

Determine the daily solids flow rate:
[(Influent flow rate) x (total solids to be removed)]
= [(6.3 L/s) x (70 mg/L)] x [(10^{-6} kg/mg) x (86,400 sec/d)]
= 38 kg/d (84 lb/d) dry solids

Total sludge flow rate:
[(Solids flow rate)/(Solids in Feed)]/[Density of Sludge] =
[(38 kg/d)/(0.01)]/[l kg/L]=3800 L/d (1000 gal/d)

(2) Compute total dry solids processed per day of filter operation:

Sludge solids = [38 kg/d x 7 d/wk]/[5 d/wk (operation)]
= 53 kg/d
Polymer = [168 kg/d x 0.02] = 1 kg/d
Total dry solids per day (sludge+polymer) = 54 kg/d (120 lb/day)

(3) Compute filter volume required per cycle (Assume a minimum of 1 cycle to be performed each day)

Filter volume per cycle
= [54 kg/d] / [(1 cycle/d) x (1200 kg/m3) x (0.30)]
= 0.15 m^3 (5.3 ft^3) of sludge/cycle

<u>Biological Sludge</u>:

(1) Compute total daily sludge solids generation rate:

Total sludge flow rate = 10,900 L/d

Determine the daily solids flow rate:
[(Influent sludge flow rate) x (solids in feed)]
= [(10,900 L/d) x [(0.02) x 1 kg/L]]
= 220 kg/d (480 lb/d) dry solids

(2) Compute total dry solids processed per day of filter operation:

Sludge solids = [220 kg/d x 7 d/wk]/[5 d/wk (operation period)] = 308 kg/d
Lime = [308 kg/d x 0.30] = 92 kg/d
Total dry solids per day = sludge+lime = 400 kg/d (880 lb/day)

(3) Compute filter volume required per cycle (Assume a minimum of 1 cycle to be performed each day)

Filter volume per cycle
= [400 kg/d] / [(1 cycle/d) x (1120 kg/in^3) x (0.30)]
= 1.2 m^3(42 ft^3) of sludge/cycle

This is a rather large press for only one cycle per day; therefore, it will assumed that at least 2 cycles per day would be performed. The filter press volume required would then be reduced by half to 0.6 m^3 (21 ft^3).

b. Selection of Efficient Filter Unit

(1) Determine the Pressure Filter Sizes Available:

From the manufacturer*s catalogs determine the sizes of various filter units. Using the basis of the most efficient and manageable filter unit assembly is the one that has the fewest operating units and provides nearly 100 percent operating capacity when one unit is out of service, and about 25 percent extra capacity when all units are in operation tabulate the filter area available with and without the single largest unit for both sludge streams.

Metal Hydroxide Sludge

Based on this method, the proper unit selection from information complied in Table E-3 would be Item B. This selection has a total of 2 units, including 1 operating units and one standby unit. This assembly will provide 133 percent of the design daily requirement when one unit is not operating, and about 267 percent of the design daily dewatering capacity when the standby unit is in operation.

Metal Hydroxide Sludge

Based on this method, the proper unit selection from information complied in Table E-4 would be Item B. This selection has a total of 2 units, including 1 operating units and one standby unit. This assembly will provide 133 percent of the design daily requirement when one unit is not operating, and about 267 percent of the design daily dewatering capacity when the standby unit is in operation.

Alternative Approaches

Because of the small amount of sludge being generated for the metal hydroxide sludge, two potential alternative approaches for providing redundancy could be used. The first approach would be to be to only provide redundancy for the biological sludge stream and use the standby press for both sludge streams or just providing the two presses. Another approach would be to obtain only the two presses required for the biological sludge and using one press for as the primary press for the sludge and using the other for primary press for the metal hydroxide sludge (using a blanking plate to reduce the volume) and as a standby press for the biological sludge stream. Using either of these approaches would provide a more economic approach to complete the required operation.

c. Additional Calculations

Based on the information presented above, additional calculations should be performed for sludge storage, conditioning, feed systems, sludge cake storage, and filtrate storage. These types calculations should follow the guidelines example calculations shown in Examples #1 and #2. In addition to these calculation, based on the specific filter press selected, requirements for sizing supporting systems such as precoating, air blowing, and media washing systems along with utility requirements, will be determined from the information provided in Section 4.0 of Appendix A and from equipment manufacturers or suppliers.

TABLE E-3
SELECTION CHART OF RECESSED FIXED-VOLUME
PLATE AND FRAME FILTER PRESS UNITS

Unit I.D.	Filter Size (mm)[1]	No. of Chambers	Volume of Each Unit (m^3)	Minimum Units Required	Total Volume with Minimum Units (m^3)	Total Units with one Standby	Total Volume with One Standby Unit (m^3)	Volume without standby Unit (%)[2]	Volume with stand by Unit (%)[3]
A	470	27	0.11	2	0.22	3	0.33	74	220
B	470 (max)	40	0.20	1	0.2	2	0.4	133	266
C	630	27	0.23	1	0.23	2	0.46	153	306
D	630 (max)	30	0.28	1	0.28	2	0.56	187	373
E	800	16	0.23	1	0.23	2	0.46	153	306
F	800	20	0.28	1	0.28	2	0.56	187	373
G	800(max)	49	0.71	1	0.71	2	1.42	473	947

Conversions: 1 m^3= 35.3 ft^3, 1 inch= 25 mm.
[1] Data compiled from actual manufacturer's data.
[2] Total volume without standby unit/actual volume required.
[3] Total volume with one standby unit/actual volume required.

TABLE E-4
SELECTION CHART OF RECESSED FIXED-VOLUME
PLATE AND FRAME FILTER PRESS UNITS

Unit I.D.	Filter Size (mm)[1]	No. of Chambers	Volume of Each Unit (m^3)	Minimum Units Required	Total Volume with Minimum Units (m^3)	Total Units with one Stand by	Total Volume with One Standby Unit (m^3)	Volume without stand by Unit (%)[2]	Volume with stand by Unit (%)[3]
A	470	27	0.11	6	0.66	7	0.77	110	128
B	470 (max)	40	0.20	3	0.6	4	0.8	100	133
C	630	27	0.23	3	0.69	4	0.92	115	153
D	630 (max)	30	0.28	3	0.84	4	1.12	140	186
E	800	16	0.23	3	0.69	4	0.92	115	153
F	800	29	0.42	2	0.84	3	1.26	140	210
G	800 (max)	49	0.71	1	0.71	2	1.42	118	237

Conversions: 1 m^3= 35.3 ft^3, 1 inch= 25 mm.
[1] Data compiled from actual manufacturer's data.
[2] Total volume without standby unit/actual volume required.
[3] Total volume with one standby unit/actual volume required.

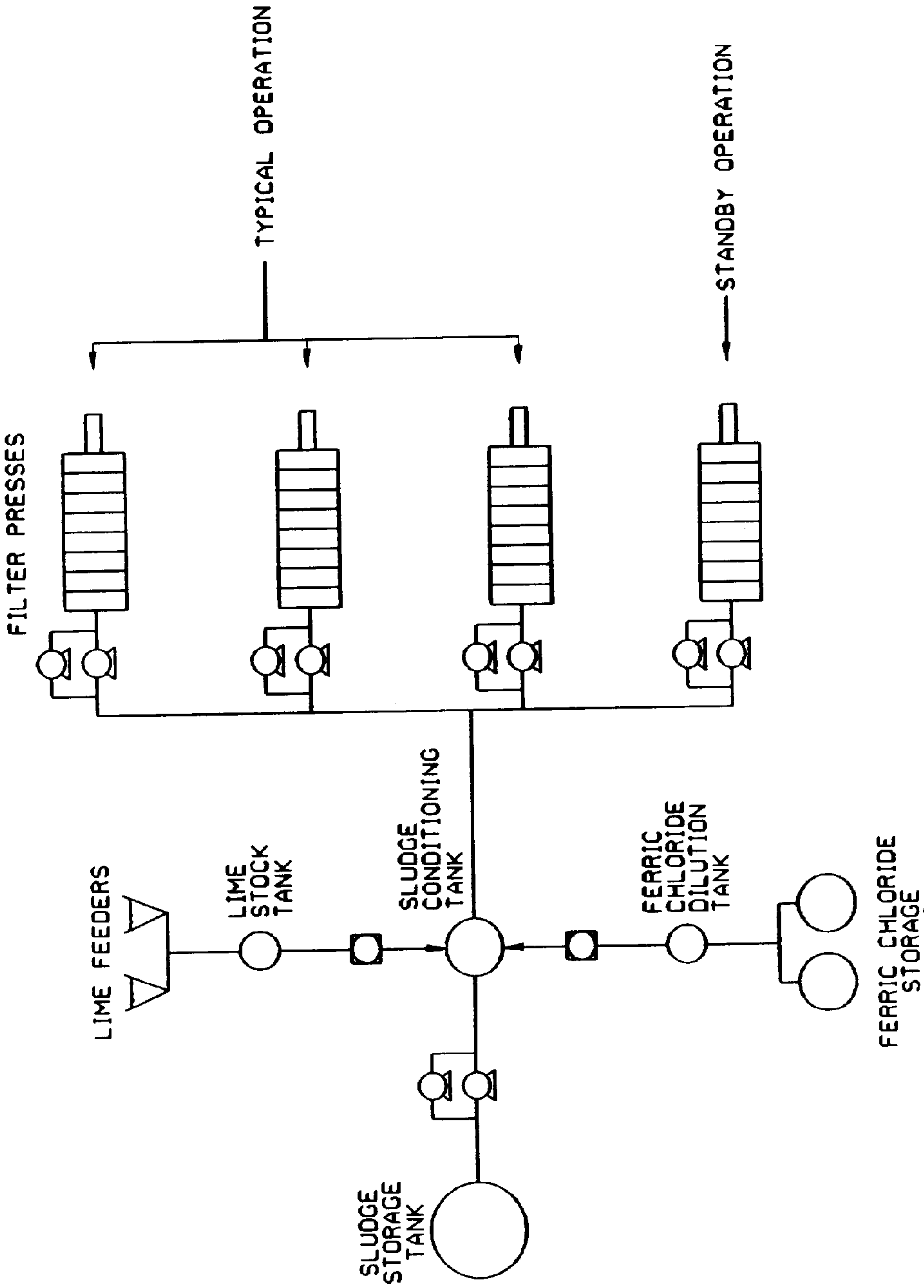

FIGURE E-1
SCHEMATIC FOR SLUDGE DEWATERING PROCESS
DESIGN EXAMPLE #1

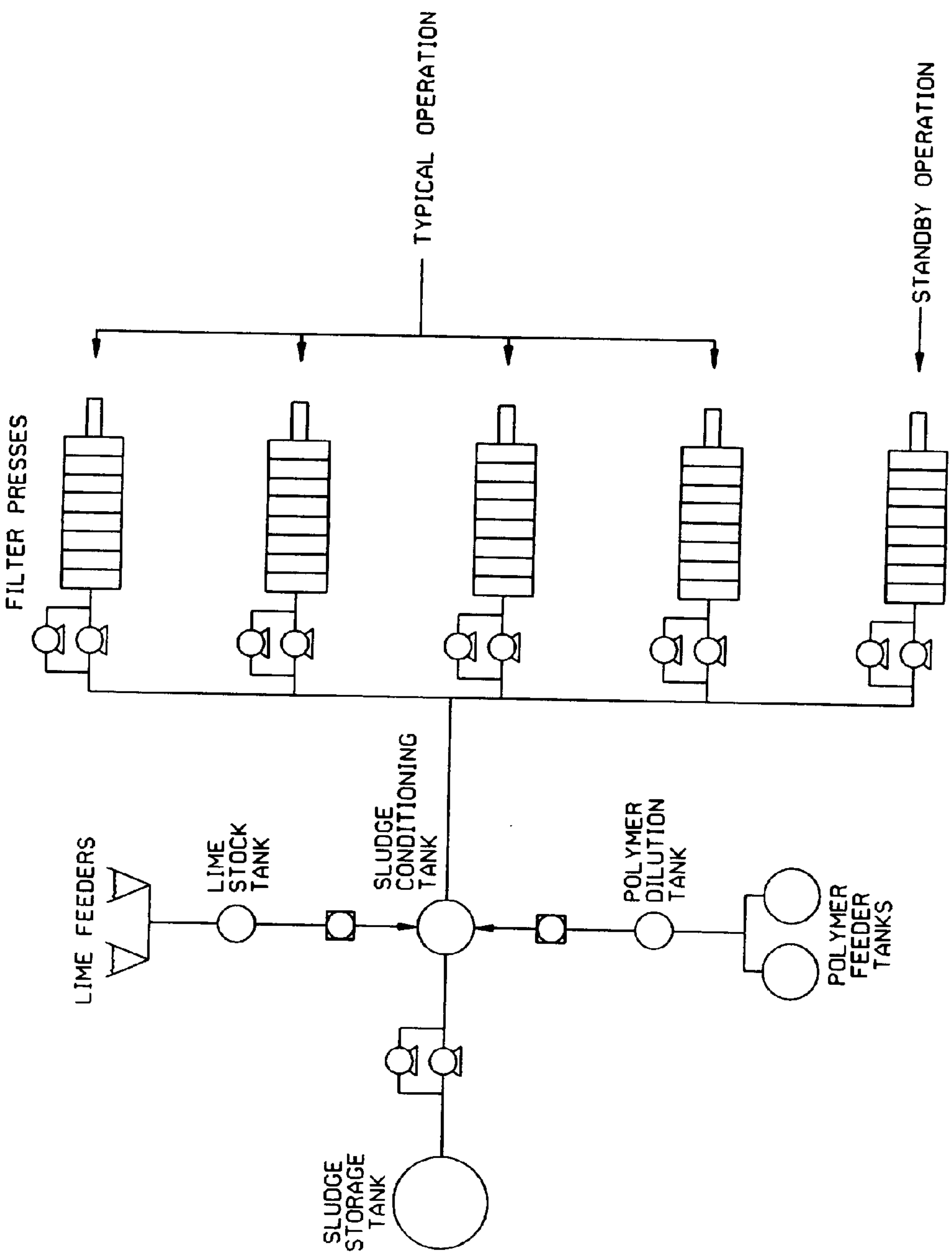

FIGURE E-2
SCHEMATIC FOR
SLUDGE DEWATERING PROCESS
DESIGN EXAMPLE #2